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JPL'S FALTERING START IN THE PRESTIGE RACE: RANGERS AND MARINERS, 1961 - 1962

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In the waning weeks of the Eisenhower administration, James R. Killian, Jr., the president's first science adviser and the president of the Massachusetts Institute of Technology, delivered a speech that was remarkable for its calm good sense during an overheated time. Killian agreed that science and technology played a vital role in foreign policy, particularly as an influence on the Third World. "Status-seekers in the community of nations" -- meaning especially the Soviet Union -- had used spectacular science and technology -- meaning particularly the space program -- "to build their prestige." He cautioned, however, that the Russians' expensive space program could not maintain an image of strength over the long pull. "True strength and lasting prestige will come from the richness, variety, and depth of a nation's total program," he said. The United States, while not content to be second best, should build its own balanced space program instead of copying the Soviets. "In the long run we can weaken our science and technology and lower our international prestige by frantically indulging in unnecessary competition and prestige-motivated projects." Killian supported a cautious man-in-space program but reminded his listeners that "the really exciting discoveries in space can be realized better by instruments than by man." The costs of manned space would be "startling," and should be balanced against other urgent national needs. "The image of America," he pointed out, "may be shaped by the quality of its inner life more than by its exploits in outer space." Finally he warned: "Do not misuse science and technology by distorting them for propaganda purposes." Killian's speech, coupled with President Eisenhower's warning a month later against the military-industrial complex, constituted a strong plea for keeping the space program in perspective.[1]

Too few persons were listening. As Killian noted, decisions would have to be made soon about the scope and pace of the space program, particularly its manned component. As the Eisenhower administration gave way to the Kennedy administration on January 20, 1961, the critics of the old regime's space program sensed an opportunity to enlarge dramatically the manned space program.

Executives of the Jet Propulsion Laboratory stood in the forefront of the critics. Having proposed an extremely ambitious program in their 1959 study, they chafed under the slower pace of the space program and of the limited role assigned them. They criticized the National Aeronautics and Space Administration for "a lack of dynamic informed technical and administrative leadership" and a lack of a sense of urgency. The discontent at JPL reflected widespread agitation within the nation aerospace establishment. The dam that had contained these forces burst under the pressure of two events in April 1961. On April 12 Yuri Gagarin orbited the earth in a Soviet spaceship, the first human to accomplish this feat. On

April 15 the Bay of Pigs invasion began. By April 19 the offensive had clearly become a disaster, and that day Kennedy called Vice President Lyndon B. Johnson into the oval office and told him to find a "space program which promises dramatic results in which we could win." In this atmosphere of shaken confidence, JPL decided to again volunteer its ideas on how the space program might rescue the nation. JPL director William H. Pickering and his assistant, Brian Sparks, concluded on April 25 that "the Laboratory holds an obligation to again examine the question of how to reduce the space gap, relative to the achievements of the Russians." Rationalizations based on scientific exploits or the overall national space record would not do, Pickering said. A new plan should be written that would "take into account the primary importance of the propaganda and geopolitical aspects of space achievements, as well as the value of missions having scientific merit."[2]

The fear that suffused JPL, and many others involved in the space program, in the spring of 1961 seemed to have arisen from two interrelated concerns. First, the Russian space feats represented a professional affront to the technological fraternity. There was an almost plaintive quality in the desire for a space program that would, as a JPL senior staff member wrote, "gain us world attention and respect." Indeed the affront was almost personal, a threat to the manhood of a generation of missile builders. "The U.S.S.R. has chosen to win the 'space race' in order to prove to the people of the world that the Communist system is more virile than the Capitalistic system," said the authors of the JPL study in May 1961.[3]

Second, as the quotation from the report suggested, technological superiority was indispensable to the long struggle between the superpowers. Even the Kennedy administration's newfound concern for the Third World as the decisive arena of conflict between Russia and America fed the drive for technological virility. Pickering argued that the Third World was watching the outcome of the technological sweepstakes in order to see where to place its bets. Moreover, technological superiority, in both quality and quantity, had been the keystone of American strategy since World War II: nuclear credibility. Since a nation presumably would not use a second-rate arsenal, American technology had to surpass the Russians' in both quality and quantity. JPL staffers, like most of the persons demanding a more aggressive space program, had spent the past fifteen years engineering the tools that undergirded nuclear credibility. Given the tendency to see a defeat anywhere as a threat to the fabric of credibility, the technological challenge was particularly important. The shadowy realm of deterrence and credibility partook heavily of prestige and images; appearances and pseudoevents substituted for the nuclear actions one had to appear ready to take without actually doing so. Thus the space program became a surrogate for nuclear confrontation -- one of the countless stage pieces, whether in the Third World or outer space, where the drama of credibility was played out.[4]

The JPL study highlighted the overwhelming importance newly invested in prestige considerations. In evaluating the desirability of missions, national prestige scored 45 points on a 100-point scale. Technology (space capability and practical nonmilitary applications) received 35 points, and science weighed in with just 20. (This weighting contrasted with the 1959 study in which JPL had ranked feasibility first and "public reaction" second; scientific and technical merit had ranked third then too.) American space goals should be putting a man on the moon in early 1967, establishing a manned lunar base in 1969, and landing a man on Mars in 1973. The main purpose was to be first, not to do "a better engineering job or obtain . . . more scientific data," the study committee said. Scientific data could be obtained on a "piggy back," or space available, basis. In keeping with the sense of urgency, the report called for greater freedom in business and contract procedures and more secrecy before launches, including if necessary a new launch base other than Cape Canaveral.[5]

Many JPL senior staff members eagerly endorsed the study. Robert V. Meghreblian thought it cut through the mistaken notions on which the existing space program was based, which he thought emphasized primarily the quest for scientific knowledge. "To my mind, a billion dollar a year space program programmed at gaining purely scientific information about outer space is a waste beyond comprehension," he said. "To discard a modern instrument of international competition which has been so brilliantly exploited by the Soviets is to jeopardize the security and prestige of the nation."

The leaders of the space science division, Al Hibbs and Manfred Eimer, argued for an all-out manned race to the moon, even though it would curtail most of that division's activities. Believing the United States' chances of beating the Russians were slim, they wanted all projects not directly related to man-on-the-moon halted and the project conducted with maximum secrecy and elaborate cover stories. Pickering adopted the report's findings and pressed for a manned moon landing as "the first big national goal" and man-on-Mars as the second. When he visited NASA headquarters in mid-May 1961 he was very encouraged to find the planning that resulted in the Apollo decision well along. "In general, the Lab's ideas and views are in conformity with these plans," he reported.[6]

The contrast between the JPL space ideology and Killian's approach could scarcely have been sharper. Where Killian argued for the primacy of science, JPL endorsed prestige and propaganda; where he looked at the total scientific and technological field, the laboratory stressed space almost exclusively; where he called for the United States to determine its own space goals, JPL followed the Soviet model; where Killian recognized the contribution of instrumented research, JPL focused on manned exploration. And to the laboratory the image of America would be shaped more by its exploits in outer space than by the quality of its inner life.

The Jet Propulsion Laboratory formulation fit well with the outlook of the new administration in Washington. To John Kennedy the "space gap" symbolized "the nation's lack of initiative, ingenuity and vitality under Republican rule," recalled one of his closest advisers, Theodore Sorensen. The arguments that American space research represented a truer measure of strength left him unmoved, for he fixed on the psychological and political impact. "The President was more convinced than any of his advisers that a second-rate, second-place space effort was inconsistent with this country's security, with its role as world leader and with the New Frontier spirit of discovery," wrote Sorensen. Correcting the "space gap" was at one with his "build-up of the most powerful military force in human history -- the largest and swiftest build-up in this country's peacetime history." On May 25, 1961, he went before Congress to give a speech on "urgent national needs" in which he called for putting a man on the moon by the end of the decade. Taking "a clearly leading role in space achievement" was essential "if we are to win the battle that is going on around the world between freedom and tyranny," he said. [6a]

The ripple effect of the president's decision, followed by congressional endorsement, was felt throughout the space establishment. The day Kennedy made his speech, NASA issued a new flight plan in which it listed JPL's lunar missions, Ranger and Surveyor, as ventures in "direct support" of the manned lunar program, soon named Apollo. JPL lunar programs director Cliff Cummings explained the effects of the decision to Johnson when he visited the laboratory on October 4, 1961: "Originally our lunar program had been oriented toward scientific and technological objectives," he said. "Now . . . the emphasis has been changed so that support of the manned operations is the primary objective, and space technology and lunar science are secondary. We believe, however, that we can accomplish the space science and technology objectives as planned, while at the same time providing essential support to the manned effort."[7]

Cummings' hopeful statement masked how complicated the lunar program had become. The scientific, technological, and manned goals were not necessarily compatible, and trying to meet all of them might impose more weight than a fragile spacecraft could lift. Furthermore these objectives had to be met on an exceedingly demanding timetable. JPL Ranger program director James Burke pasted a picture of a Soviet Venera spacecraft on his wall and added a proverb: "The better is the enemy of the good." Laboratory engineers filed papers headed "Beat the Russians" and decorated them with doodles that showed clocks with hands at the eleventh hour, swinging pendulums, and the words "FLY SOON" cascading in block letters across the page. So far as JPL was concerned the fact of building an operational spacecraft and accomplishing a mission first overshadowed what it did. In line with the ideas of prestige, derived from the concern with credibility, appearance would overshadow substance.[8]

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If the Ranger series labored under the need to demonstrate prestige above all else, three other areas also raised potentially critical problems -- the design and construction of the spacecraft, JPL management, and the unclear and sometimes contradictory objectives of the program.

The design of the spacecraft had been inherited from the Vega program, which had had its origins in the Juno IV program. This had several implications for Ranger. First, and most critical, the Ranger spacecraft was more complex than a lunar vehicle needed to be, especially in the area of guidance and control. Vega had included a strong planetary thrust -- a flight to Mars in 1960 had once been on its timetable -- with spacecraft designed accordingly. Communication from planetary distances was one of the principal problems; it necessitated a high-gain antenna that would point continuously at the earth, which, in turn, required that the spacecraft have full attitude stabilization in all three axes -- roll, yaw, and pitch. JPL engineers also decided that the longitudinal axis should usually point toward the sun because they were uncertain whether the onboard sensors could detect the earth from planetary distances. This further complicated guidance and control, but it offered as a byproduct that solar cells on fixed panels could be used as the main source of electrical power. Ranger also required an onboard computer. For a 66-hour lunar flight battery power would have sufficed instead of solar panels, and a high gain antenna was unnecessary.[9]

The complex guidance and control system represented a big step over the Explorers and Pioneers, which had been stabilized simply by spinning the vehicle along its roll axis. The added complexity placed a heavy strain on JPL's electronics division. James Burke, the Ranger program director, had little background in guidance and control and relied on one of his deputies in this area. The strain told particularly when Mariner's guidance and control demands siphoned many key people away from Ranger in 1961-62. In many cases unsupervised junior engineers and technicians were designing and fabricating Ranger's guidance and control assemblies. Guidance and control proved to be the project's Achilles heel.[10]

Ranger's second inheritance from Vega was "design for success." Ranger tended to be an all-or-nothing machine. Mission success depended on a long train of items working satisfactorily in sequence. The failure of any one component, particularly at the beginning or in the middle of the sequence, could abort the entire mission; there was little provision for partial mission success, and little backup or redundant equipment that could function if the primary unit failed. The Vega design had utilized the expected allowable weight to the fullest, and when Ranger's weight was cut, the stress became severe. Everything had to work right for the mission to be a success.[11]

This design characteristic necessitated engineering excellence in every detail -- something the Ranger management structure could not provide. The detailed design and actual fabrication of the spacecraft devolved on the technical divisions, where the ongoing work of the laboratory was carried out. But these divisions found their attention divided among several projects at once in 1962 -- Ranger, Mariner, Surveyor, and perhaps other smaller ventures. The division engineers were responsible to their division chiefs, not the Ranger project manager, James Burke. He had to rely on the divisions to assign and supervise the personnel. With their attention divided, division chiefs and their subordinate section chiefs seldom had a detailed grasp of the needs of a particular project. Burke had little power to demand; he had to rely on negotiation with the powerful division heads. If they could not provide detailed engineering guidance, it had to come from his undermanned project office. The harried project director exerted little influence on the design of the spacecraft. Burke estimated that he spent as much as sixty percent of his time dealing with NASA headquarters; his two deputies were spread too thin to provide detailed supervision. Some of this responsibility devolved on the systems division, but it had neither the personnel nor the clout to follow through. Design and fabrication quality depended chiefly on whether the individual who did it was satisfied; changes in design could often be made with inadequate consideration of the effects on other components; and there was no central clearing house to collect and evaluate failure reports. Supervision of outside contractors was lax.[12]

Under the best of circumstances this organization would have had problems, but other factors taxed the structure as well. One was personnel. Mariner, directed at planetary flight, was a more exotic project and attracted many JPL personnel away from Ranger. The laboratory simply did not have enough experienced personnel to support two major projects at the same time, plus the beginnings of Surveyor, and other smaller activities. JPL personnel grew from 2600 in 1960 to 3500 in 1962; some divisions reported that as many as sixty percent of their professionals had less than two years' experience at the laboratory. Its budget mushroomed from $35 million in fiscal year 1958 to $132 million in fiscal year 1962; while much of this was funneled to off-lab contractors, the supervision of these business arrangements and their products added many new problems. Another was sterilization. Since Ranger was supposed to impact the moon, the machine was to be sterilized so as not to contaminate any life that might exist there. Portions of the spacecraft were heated to temperatures as high as 257 degrees Farenheit for 24 hours. The sterilization measures were controversial; some persons felt they were unnecessary to start with, and others believed they seriously degraded spacecraft reliability, particularly electronic components. A NASA study in 1962 suggested that sterilization contributed to spacecraft failure and should be abandoned; the JPL failure-review board, on the other hand, virtually ignored sterilization. In any event, sterilization added uncertainty to an already compromised object.[13]

The Jet Propulsion Laboratory's internal problems on Ranger were complicated by difficult relations with NASA headquarters. Most of these focused on Ranger mission objectives, often the role of science. As originally conceived Rangers 1 and 2 would constitute Block I; while carrying some scientific experiments, their primary purpose was to prove out the technology. Obsessed by schedule, Burke was especially adamant that Block I proceed on time and that anything that interfered with gaining early flight experience should be discarded. He was infuriated, therefore, when the Atomic Energy Commission asked to add a secret experiment to detect above-ground nuclear explosions, known as Vela Hotel, just before he froze the final design of Rangers 1 and 2. NASA headquarters -- less committed to schedule and perhaps less aware of the engineering problems -- acceded to the request. The Vela Hotel episode added "vigor to the technology-science controversy," Burke complained, "and encourage[d] undisciplined efforts by our own [JPL] science people to get Headquarters to order us to wait for them if necessary."[14]

For the Block II Rangers -- flights 3-5 -- NASA had specified that science would be paramount. This block carried added experiments which included a television camera to return closeup photographs, a seismometer to detect seismic activity, and a gamma-ray spectrometer to determine the chemical composition of the surface. JPL engineers continued to insist, however, that development of the technology should take priority, and headquarters eventually agreed.[15]

As JPL carried out the final fabrication and the launches of Rangers 3 through 5, it also battled NASA headquarters over the place of science on Block III, Rangers 6 through 9. The Ranger program had been awarded the four additional flights in 1961 as part of the expanded Apollo program. At first glance the objective seemed clear; Block III would support manned flight objectives. But Homer Newell, head of the Office of Space Sciences at NASA, was determined to get as much science onto Ranger Block III as he could. Newell waged a lonely fight for science against the dominant ethos and bureaucratic momentum of the manned program. Since science was usually the first goal to be discarded, he fought for every opportunity to get experiments on board, even if the technologically oriented groups found them an interference. Some extra weight was available, so OSS wanted to add eight experiments weighing a total of seventy pounds to Rangers 6 through 9. Many JPL staffers termed these experiments "trinkets" and felt they would jeopardize the success of Ranger, none of which had yet succeeded.[16]

Burke balked, raising hackles at OSS. Pickering supported him. "We at JPL are now in favor of a faster-paced and technically simpler program than the ones that we have in the past advocated or at least accepted," he said. "We strongly support the . . . [Space Science Board] recommendation that lunar environmental and engineering data for Apollo design be sought with urgency and even, if necessary, at the expense of data having greater intrinsic scientific value." The director's viewpoint seemed somewhat surprising in view of JPL's later identification with the primarily scientific aspects of the space program, but it was consistent with the outlook embodied in the 1961 laboratory report. In 1962 the lunar program to JPL was still a race with the Russians.[17]

The controversy over the relative merits of pure science as opposed to data for Apollo was finally settled at NASA headquarters in the fall of 1962. The warring NASA offices agreed to coordinate their plans; some of the scientific experiments could be designed to provide the information the manned side wanted. Apollo emerged first among equals. The resolution of the controversy had consumed several months, and it had inflamed relations between NASA and JPL. It had created new design problems and controversies as goals were hammered back and forth. The basic objectives of Mariner, by contrast, were never in doubt. Stretching over most of the period when Block II hardware moved from fabrication through launch, the controversy diverted energy from a project that was already in serious trouble.[18]

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Despite problems that might have suggested a slower approach, JPL confidently pushed the first two Rangers to the launching pad. Burke was in a hurry. The hope that an early shot might beat the Russians continually lured the laboratory. JPL was also heavily influenced by its arsenal experience in building missiles. JPL stopped design work on the ground and began flight tests earlier than with spacecraft. One expected that several of the early missile flights would fail, some perhaps disastrously; flight tests were an integral part of the final design process. Spaceflight, however, was much more costly and launch opportunities very much rarer. A series of flight tests was an impossible luxury; space machines had to perform successfully from the start. Through Ranger the Jet Propulsion Laboratory would have to unlearn its arsenal experience.

The Ranger spacecraft that JPL trucked to Cape Canaveral, Florida, in a special air-conditioned van was a sophisticated machine.[19] The aerodynamic shroud that protected the craft during launching gave little hint of the complex systems underneath. The base of the spacecraft was a hexagonal block five feet in diameter to which modules containing the sophisticated electronics that composed the life-support system were bolted. A - foot tower extended above the base on which the scientific equipment and a low gain antenna rode. The solar panels and a hinged high gain antenna were drawn up along the tower and then during space flight unfolded like the wings of a butterfly. The scientific experiments on Block I were in order of priority: solar plasma detector, magnetometer, trapped radiation detector package, ionization chamber, cosmic-ray telescope, Lyman alpha scanner, and micrometeorite detector. The final hardware for Block I weighed 675 pounds, which was 164 precious pounds less than could have been accommodated. Difficulties in the development of the launch vehicle had kept JPL guessing on the final weight that could be lifted, and by the time the exact figure was known, the schedule-conscious laboratory had frozen the design. The extra weight could have been put to excellent use in redundant engineering features to insure spacecraft reliability.

As it happened, however, the Block I spacecraft never got to demonstrate what it could do. An Atlas-Agena two-stage rocket would hurl the spacecraft into its flight path, which, like other aspects of Ranger development, was one step more advanced than a lunar mission required. Developed by General Dynamics-Astronautics in the mid-1950s as the first United States intercontinental ballistic missile, Atlas stood five stories high and developed 360,000 pounds of thrust, equal to that of six Boeing 707 jetliners. Instead of a direct ascent to the moon, Ranger would be launched first into an earth satellite, or parking, orbit by Atlas. Then the second-stage dual-burn Agena, developed by Lockheed, would provide 16,000 pounds of thrust that would kick Ranger into its deep space trajectory. As Agena and Ranger circled the earth together, trajectory planners could compensate for celestial motions and extend the time of the launch window. This added flexibility, which was particularly important for the limited launch intervals of planetary flights, increased the chances of a successful flight if the countdown should be delayed.

After weeks of complicated preflight tests and mating procedures, the ill-starred countdown for Ranger 1 began three days late, on July 28, 1961. Uncertainty clouded the outlook, particularly for Agena, which had had a difficult development process. NASA officials estimated the chances of a successful launch of Atlas-Agena at only 0.5. Two countdowns were aborted because of various problems. The third went smoothly until early in the morning of July 29, when, twenty-eight minutes before launch, a failure of the commercial power in the area plunged the Cape into darkness. A day later the fourth countdown began, only to be scrapped when, during a routine test, the spacecraft went into its space act while sitting on the launch pad. The explosive squibs fired, the solar panels unfolded under the shroud, and the experiments began to hum. An errant power discharge from one or two of the scientific experiments seemed to have caused the aberration, although the case was never pinpointed. Hastily removed from Atlas-Agena and sent back to its hangar, the spacecraft was rewired and its damaged parts replaced. The process took nearly a month. The delay was embarrassing and vexing, particularly to Burke, who took the incident as an unfortunate example of how scientific experiments could interfere with the technological goals that were uppermost to him. On August 22, 1961, the next available lunar opportunity, the fifth countdown proceeded smoothly, and at dawn Ranger 1 roared away.

Before long, however, the tracking stations reported bad news. The Agena second burn had gone badly -- a faulty switch had closed too soon and cut off the supply of propellant. The spacecraft's trajectory called for an apogee of about 620,000 miles and a perigree of several hundred miles; instead its actual path reached a high point of only 313 miles and a low point of 105 miles. Designed for deep-space flight, Ranger could not meet the demands of the near-earth satellite orbit in which it was caught. Every ninety minutes the craft passed into the earth's shadow and lost solar power and orientation; as the vehicle reemerged into the sunlight, it had to realign and stabilize itself anew. Consuming the nitrogen gas of the attitude control system like a drunk with a bottle of cheap wine, Ranger 1 exhausted the gas in a day. The craft began to tumble. The solar panels lost their alignment with the sun, leaving only its battery for a source of power. Telemetry continued to flicker results of the experiments and the performance of the spacecraft system to earth for three days. But soon the battery failed and on August 30, Ranger 1, blind and mute, slipped into the atmosphere and was incinerated. JPL engineers considered, however, that the spacecraft's valiant struggle under impossible conditions had proved its basic design was good. They optimistically readied Ranger 2.

But the second flight of Ranger ran into similar problems. An investigation of Agena's hydraulic problems delayed the launch from mid-October to November 17, 1961. Atlas lifted Ranger successfully, but again the Agena second burn went badly. The spacecraft's orbit was even lower than before, and after just twenty hours of flight, the machine cascaded to a fiery demise. Science on Ranger 2 was nearly a washout. Ironically the Vela Hotel experiment, which had been added only over JPL's strenuous objections, was one of the few experiments on either flight of Block I to return much useful data.

As preparations began for Block II (Rangers 3 through 5), JPL project managers, particularly Burke, pressed for more flight experience as soon as possible. Block II was supposed to have a stronger scientific content, but Agena's failures in Block I increased JPL engineers' desires to test out the spacecraft -- in effect, to continue giving priority to the technological over the scientific goals. The issue came to a head over the trouble-plagued seismometer capsule subsystem, which was designed to detect seismic activity during the course of the two-week lunar day. The delicate instruments of the capsule, under development by Ford Motor Company's Aeronutronic Division, had to operate after being rough landed on the moon with a residual velocity of 136 miles per hour and a force of 3000 g. Drop tests in the Mojave Desert cast doubt on the capsule's survivability; the heat sterilization the capsule underwent also seemed to degrade reliability. Oran Nicks, director of the lunar and planetary program office at NASA, argued that Ranger 3's flight should be postponed until the capsule's problems were fixed. To do otherwise for this key experiment, he thought, would distort the objectives of Block II. Pickering and Burke felt, however, that the various in-flight processes and operation of the lunar televisions system could be determined only by a flight test; even if the capsule subsystem failed on the moon, the flight experience would be invaluable. And besides, the chance always existed that a successful mission would surpass the Russians. In any case two more flights remained in Block II that could serve science. Edgar Cortright, deputy director of the office of space sciences at NASA, accepted the JPL position and authorized a launch of Ranger 3 on schedule.

The third Ranger thundered upward on January 26, 1962, after last-minute problems with the launch vehicle had run the blastoff to within an hour and fifteen minutes of the time remaining in the launch window. This time the Atlas-Agena performed well. At first the Ranger trajectory looked right. But soon the tracking network revealed that because a sign had been inverted in a computer code, Ranger's path was a mirror image of what it should have been. Although the error would limit the time available for picture taking, some would remain. Meanwhile all other parts of the spacecraft functioned well. On January 28 the spacecraft entered the period known as "lunar encounter," and JPL transmitted commands to correct the spacecraft's position as much as possible. But after executing some of the orders, Ranger's signal strength began to fluctuate widely; the antenna was no longer pointing to earth, as it should have been. The central computer and sequencer on the spacecraft had failed. Its earth and sun sensors out of commission, controlled only by its gyroscopes, Ranger continued to turn. The television cameras operated, as they were supposed to, but because of the spacecraft's aimless drift about its axis, the pictures did not show the moon, just empty space studded by reference crosses. Ranger rushed past the moon at a distance of 23,000 miles and headed into solar orbit. The flight of Ranger 3 was even more excruciating than the first two. The near miss was more tantalizing than the grand failures, and the onus for Ranger 3's shortcoming lay squarely with JPL, particularly its guidance and control engineering. The laboratory scrutinized the possible reasons for the computer failure but without conclusive result.

For Ranger 4 a combination of well founded optimism and wishful thinking prevailed. The chances of hitting the moon appeared good, and some useful data probably would be returned. But JPL acknowledged privately that the odds of complete mission success were "relatively remote," and it readied a public information plan that was "flexible enough to allow emphasis to be placed on a successful experiment."[20]

Ranger 4 scored a direct hit on the far side of the moon on April 26, 1962, but this mission was an even bigger disappointment than Ranger 3. After perfect operation by Atlas-Agena -- a midcourse correction had not even been necessary -- the spacecraft had failed to operate at all. The master clock in Ranger's central computer and sequencer had failed, which meant that no timed functions could take place and that the machine could not act on commands from earth. "All we've got is an idiot with a radio signal," said a NASA official.

It was possible to find a silver lining in the direct hit -- the first time a United States vehicle had succeeded in reaching the moon. Other parts of the space program were going well: John Glen had orbited the earth recently, and the Saturn rocket that would power Apollo had just completed a perfect flight test. NASA administrator Webb insisted that the man-in-space program, of which Ranger was an integral part, remained on schedule. But crashing a garbage can on the moon offered no support for Apollo or for science. The Soviet Union had deposited a pennant on the moon in 1959, albeit with a less sophisticated spacecraft. Their level of anxiety and embarrassment rising, JPL engineers redoubled their efforts to insure that Ranger 5 worked.

* * * * *

During Ranger's four disappointments, the Mariner program -- similar in design but different in organization and execution -- made rapid progress. Two Mariner launches interrupted Ranger's schedule in August 1962 and produced JPL's first notable space victory since Explorer I.

Mariner had originated as a planetary mission that would be propelled by Atlas and Centaur, a rocket under development by that was more powerful than Agena. But Centaur's development problems accumulated until in the summer of 1961 it became clear that the rocket would not be ready for the Mariner launches the following year. The original fall-back plan had called for launching the first two Mariner A's as interplanetary probes in 1963, then firing the next two at Venus in 1964; the first Mariner B's, which were more sophisticated, would fly to Mars in 1964. Another possibility had been to cancel Mariner A and divert the entire JPL effort to a combined Mars and Venus mission for Mariner B in 1964. Under both plans the 1962 Venus launch opportunity would pass untried. JPL conducted a crash review of Mariner and came up with an imaginative approach that promised to hold losses to a minimum and still achieve some of the program's objectives in 1962. The Atlas-Agena used for Ranger could power a Venus flight, if the spacecraft were lighter. The laboratory proposed stopping work on Mariner A and fashioning a new spacecraft, known as Mariner R (from Mariner-Ranger), from Ranger, Mariner A, and some new components. The solution had its drawbacks. It entailed a loss of $3 to $4 million, and, while it promised good interplanetary scientific experiments, the planetary experiments were minimal. Nonetheless, as a way to inaugurate the planetary program, and to schieve an American space first, Mariner R had much to recommend it. NASA approved the reprogramming and JPL began working on Mariner R in the fall of 1961.[21]

Although the reorientation first seemed to pose colossal headaches, it turned out to be a blessing in disguise. It forced a design review; coming midway through the project, the review was more comprehensive and took better account of the system as a whole than had happened with Ranger. Mariner program manager J. N. James also worked with Lockheed to cut 100 pounds from the Agena. Mariner further benefited from a stronger project organization. As problems multiplied in the spring of 1962, James decided he needed a spacecraft systems manager; Dan Schneiderman took on the job full-time. James established a matrix organization in which representatives of six technical divisions interfaced with systems personnel who were assigned to the project full-time. Mariner also used more formal written documents, such as flow charts that amounted to promises by one division to supply equipment to another by a certain date, and more rigid quality control. In this way shortcomings tended to come to the attention of someone other than the engineer or group responsible, which increased the chances of getting things fixed. The imposition of a project organization over the regular division structure posed problems, James acknowledged. He wanted more power. He got "what he needed from the divisions by wrangling." At times he had to rake the division chiefs, but he had to proceed with caution so as not to jeopardize his position with the divisions on whom he depended. Nevertheless, because the technical divisions represented the ongoing work of the laboratory, he did not favor a fully projectized organization. One final advantage Mariner R enjoyed was freedom from wrangling with NASA. James estimated that he spent only twenty-five hours dealing with headquarters during the program. In part this represented his managerial skill, in part NASA's lesser interest in Mariner than Ranger.[22]

Paradoxically Mariner was a simpler project than its lunar counterpart. James proposed, and NASA accepted, simple objectives. These goals were "to pass near the planet, to communicate with the spacecraft from the planet, and to perform a meaningful Planetary experiment." To carry out these objectives six relatively simple experiments, weighing 41 pounds, rode on Mariner R. Two were to provide information solely on Venus. They were a microwave radiometer experiment to take the temperature of the planet's surface and an infrared radiometer experiment to gather data on the thermal energy in the Venusian atmosphere. The other four experiments would operate in space and in some cases also near the planet. They included a magnetometer experiment, a charged particle experiment, a plasma experiment to study the solar corona, and a micrometeorite experiment to measure the density of cosmic dust particles. The 447-pound spacecraft was based on the hexagonal concept used in Ranger.[23]

Mariner 1, launched from Cape Canaveral on July 22 had the most disastrous flight of any of the Mariner or Ranger series. After a flight of less than five minutes, the vehicle was destroyed by the range safety officer because it took a wildly erratic path. The tiniest of details had caused the gigantic error: a hyphen had been omitted from the launch vehicle guidance equations. Mariner 2 was launched on August 27, 1962, and seemed destined for a similar fate. But the guidance malfunction in the Atlas was overcome just before the Agena second stage was to separate. A preflight study had estimated the reliability of the spacecraft at 42 percent, but it performed flawlessly. "The spacecraft obediently extended its solar panels and high-gain antenna, acquired the sun and earth, stabilized in space, and flawlessly executed a necessary midcourse correction maneuver." Some 108 days later, Mariner 2 would pass within 25,000 miles of the surface of Venus.[24]

Enroute to Venus Mariner 2 sent back unparalleled scientific data on interplanetary conditions. The spacecraft provided by far the most detailed confirmation of the "solar wind," solar plasma that flowed out from the sun throughout the four-month mission. The cosmic dust experiment registered only two impacts of particles during the flight. Since spacecraft encountered 10,000 times as much material near the earth, the findings lent support to theories that meteorites blasted loose bits of the moon which in turn became trapped in the earth-moon system. The Mariner 2 flyby of Venus on December 14, 1962, began building the case that Venus, which because of its mass and orbit was sometimes called "the earth's twin," was in reality quite different. Unlike earth, Venus exerted no change in magnetic fields or plasma flows near the planet; if Venus had radiation belts, they were less extensive than the Van Allen belts that girdled Earth. The radiometer data revealed that dense, cold clouds surrounded Venus and that its surface temperatures reached approximately 800 degrees Fahrenheit.[25]

The scientific returns, while interesting, did not have the dramatic impact of other space probes, such as Explorer's discovery of the Van Allen belts or later landing missions. They tended to eliminate various hypotheses rather than highlight dramatic breakthroughs. The returns, particularly for Venus, were "relatively scant," space science chief Newell acknowledged. "The principal value of the Mariner II accomplishment must still be regarded as laying the groundwork for an even more extensive investigation of the planets to come." Newell praised JPL's ingenuity in making an about-face when Mariner A met its demise. Three technological achievements drew particular attention. First, Mariner proved that spacecraft could be launched to neighboring planets with accuracy. Second, the spacecraft set a communication record. Using a transmitter that generated only 3.5 watts of power, Mariner 2 communicated with Earth from 54 million miles away. Third, many of the uncertainties of space travel began to fade as Mariner, penetrating deeply into unexplored regions, performed unattended for months. And Mariner 2 had put the United States a leg up on the Soviet Union in planetary exploration. Since the United States had focused the world's attention on putting a man on the moon, however, the Mariner success served also to increase the pressure to perform well with Ranger.[26]

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The Mariner interlude gave Ranger personnel a five-month breathing space in which to rework the spacecraft. They made several important changes. Analysis of the Ranger 4 flight indicated that the failure had probably occurred because of short-circuiting in the electronic brain during the few seconds between separation of the spacecraft from Agena; steps were taken to isolate the "hot" lines in the connector. Freed of earlier weight limitations, JPL engineers added a backup clock and another nitrogen gas bottle to protect against failure. The nagging problem of sterilization was compromised. Rolph Hastrup, the JPL engineer in charge of heat sterilization, argued that the whole program should be abandoned. But the laboratory and NASA decided to keep the heat treatments but waive it for certain critical parts.

Launched into a leaden sky on October 18, the last Ranger for science moved easily into its lunar trajectory. But a little more than an hour into the flight, alarms began sounding throughout the space network. The temperature in the central computer and sequencer shot up; electrical power from the solar panels had failed. The craft switched to battery power, but performance remained erratic; in any case, the batteries would be exhausted long before Ranger reached the moon. Worse yet, the telemetry-to-teletype encoders at the South African and Australian tracking stations had also failed, and the telemetry from the spacecraft was too garbled to be of any use. The hopes of the scientists plummeted. Burke and his colleagues decided to salvage what they could by attempting a midcourse maneuver that should make Ranger, although dead, hit the moon. The midcourse maneuver began successfully, but soon further electrical shorting occurred, telemetry blinked on and off, and the maneuver failed. The battery had run down. The radio transmitter went dead, the gyroscopes stopped, and the spacecraft began to tumble. Ranger 5 failed even more dismally than Ranger 4. Turning cartwheels on its way to solar orbit, the fifth Ranger missed the moon by 450 miles. After five flights Ranger had yielded hardly anything for science or Apollo. No one found a silver lining. The Ranger program was a shambles.

Both JPL and NASA convened special failure-review boards at once. The six-man committee at the laboratory delivered a strong indictment of Ranger operations and management to Pickering on November 13, 1962. The board expressed concern about the design process for both Ranger and Mariner. Neither had had sufficient systems design review, which it feared was typical of JPL practice. Burke now felt also that the design erred in placing too much reliance on the central computer and sequencer. Nonetheless the basic design, as the essentially similar Mariner suggested, led the panel to believe Ranger could work. The problem lay in the detailed engineering execution, they stressed. Ranger 5's in-flight failure appeared to be localized in a power switch and logic module; examination of spare units revealed many weaknesses in design and assembly -- and the board feared "comparable deficiencies exist[ed] throughout the spacecraft." During systems tests fourteen failures -- any of them serious enough to cause mission failure -- proved that engineering excellence was lacking. The rudimentary failure-reporting system relied heavily on personal contact with little followup or formal supervision.[27]

The board traced many of these problems to the operational methods of the lunar project office. Drawing on Mariner experience, the committee believed that JPL organization could work, but it demanded "a strong project manager of on-Lab activity." Burke had spent too much time on relations with NASA, leaving little time for leadership of the various technical units. He had exercised "little influence on JPL spacecraft project execution," the board found, and attempts to delegate his functions proved ineffective. The board called this style of management "a major hazard to project success and a general underlying cause of the failures experienced." A related managerial problem arose from the nature of the laboratory. It was ill suited to what was essentially an industrial function: turning out repetitive pieces of equipment. Many persons were atracted to JPL because they liked the challenge of designing new one-shot items and then moving on to design another. Cummings thought Ranger had the "first team" on flights 1 and 2 but that the greener grass of Mariner had drawn them away from flights 3 through 5. JPL quality control chief Brooks Morris observed that JPL perhaps suffered from having "too many engineers experienced in <u>starting</u> new jobs and not enough experienced in <u>finishing</u> them."[28]

A comparison between Ranger and Mariner was instructive. The Mariner R design actually represented attempts to correct Ranger shortcomings more than did the hardware being fabricated for Rangers 6-9, the board said. Mariner's failure-reporting system had been stricter. Perhaps of greatest significance, Mariner director James had to spend little time dealing with NASA and could exert the detailed supervision that eluded the Ranger project. His office operated as its own executive without delegating functions to the systems division or some other unit. Mariner felt its director's influence at several key points. It further benefited from an influx of top personnel from Ranger, and the very nature of the Venus mission as a one-time possibility encouraged the pursuit of excellence.[29]

The board recommended several stern measures before another Ranger flight was attempted. Of the several managerial changes, the most important were that Burke be replaced by "someone new to the Project, and someone with a Laboratory reputation for successful project management as well as a reputation for dogmatic pursuit of excellence." The panel urged a general tightening of managerial techniques, particularly in formalizing design and testing procedures and involving the regular JPL line organization, particularly the section chiefs, more fully. The Ranger 6 spacecraft should be converted into a design evaluation vehicle. Finally, the planning for Rangers 10-14 and any subsequent models should be modified in line with the reevaluation of Rangers 6-9 design.[30]

However harsh the JPL board's report may have seemed, the NASA findings were still more grave. Known as the "Kelley board" after its chairman, Albert J. Kelley, the NASA committee filed its damning report on November 30, 1962. Similar in many respects to the JPL analysis, the Kelley report made two additional points of significance. First, it indicted JPL's emphasis on schedule above all else as a "shoot and hope" approach, "i.e., shoot enough and hope that sooner or later one of a series will indeed work." This approach undermined excellence in design and execution and encouraged meeting a flight date instead of slipping schedules for greater reliability. Such a philosophy might work for simple and relatively inexpensive designs, such as the Sergeant missile, but for sophisticated and costly projects, such as Ranger, the number of launches necessary to produce a successful mission grew very large and prohibitively expensive. Many persons at JPL -- Burke in particular -- resented the "shoot and hope" characterization and noted that NASA had contributed to the space race atmosphere that encouraged emphasis on schedule. The report nevertheless struck a vein where the laboratory was vulnerable. JPL had called for an even more fast-paced program than NASA in 1961, and when the national agency had at times wanted to slip the schedule the laboratory had insisted on shooting soon. The arsenal experience, coupled with JPL's too confident belief in its ability to meet the severe demands of the new space technology, misled the laboratory.[31]

Second, the Kelley board urged an end to heat sterilization -- a subject the JPL committee had all but ignored. The NASA group worried that sterilization degraded the performance of even the best equipment and that on those parts of Ranger that were "marginally designed to begin with" the consequences could be "extremely serious." JPL, the report concluded, had not "applied to Ranger 'buses' the high standards of technical design and fabrication" that were necessary to attain success. The weaknesses were "so extensive" that spacecrafts 6-9 were not likely to perform any more successfully than Rangers 3-5.[32]

Several recommendations followed. Rangers 6-9 should be tested to see whether they could be improved enough to merit launching. An industrial contractor should assume responsibility, under JPL direction, "for system management, including redesign, fabrication, assembly, and test of the spacecraft" on Rangers 10 and following as soon as possible. Laboratory project management should be strengthened with adequate staffing, clear lines of authority, formal design reviews, and strict quality control. The relationship between JPL and NASA also needed reevaluation and headquarters should not award the laboratory any major new flight projects until the Ranger situation was satisfactorily resolved. Closer NASA monitoring of Ranger and JPL also was suggested. Mission objectives should be clarified and simplified. Finally, heat sterilization should stop at once.[33]

A chastened JPL regrouped. Even though the Kelley board report was harsher than JPL staffers had expected or felt warranted, stringent actions could not be avoided. First the director replaced Burke and Cummings. Robert J. Parks, who had run the planetary program, also assumed Cummings' lunar duties; Harris M. "Bud" Schurmeier, took over from his Caltech classmate Burke as Ranger project manager. Pickering also curtailed the "feudal independence" of the laboratory's technical divisions. Section chiefs had to get the consent of project managers before transferring personnel from one project to another; laboratory-wide standards for quality assurance and flight acceptance testing were laid down. To ride herd on these procedures Brooks T. Morris was given added authority. And to remove any remaining doubt, Pickering installed Ranger as the laboratory's number one priority.[34]

By mid-December 1962 JPL and NASA officials had hammered out new guidelines for Ranger along the lines of the Kelley report. First, the objectives were simplified. Flying in support of Apollo, Ranger would have one objective: television. As Schurmeier put it: "A few TV pictures of the moon, better than those taken from earth, is the only mission objective. No advanced development experiments or additional scientific instruments will be carried!" Advanced technology for the planetary program became a byproduct, not an objective, of Project Ranger. All the secondary scientific experiments -- the notorious "trinkets" -- were ditched. Their precious pounds would be devoted to redundant engineering features to make the spacecraft more reliable. Second, heat sterilization was abandoned, as was terminal sterilization of the spacecraft with ethylene oxide gas, and Ranger's sterilized parts were to be replaced. Third, Ranger 6 was postponed indefinitely until JPL and NASA were satisfied the venture had a high probability of success. More than a year would elapse before another shot was tried, in January 1964.[35]

Would these measures work? No one knew. Morale had virtually dropped off the charts. The technical and managerial demands remained formidable. If Ranger worked, Apollo would be the beneficiary. While Homer Newell continued to insist gamely that television pictures of the moon had substantial scientific value, the failure of Ranger Block II had been a decisive defeat for space science. JPL had contributed to that defeat both by its insistence on the primacy of engineering goals and by that very subordination of science to prestige and propaganda purposes that James Killian had warned against. Indeed, without pressure from NASA, the laboratory would have pushed flight schedules even faster and reduced the role of science even more.

Paradoxically, in the midst of Ranger's inglorious streak, JPL's success with Mariner 2 inaugurated the laboratory's sterling series of planetary missions for which the institution eventually would win renown for its contributions to science. But at the close of 1962 JPL was still entangled in the prestige race that it had helped to create. The laboratory had entered the most critical phase of its forty-year history. Not only did it have to rework Ranger. The contract with NASA also came up for renewal, and the misunderstandings and accumulated resentments and disappointments that surfaced during the negotiations eventually produced substantial alterations in the character of the laboratory.

NOTES

1. James R. Killian, Jr., "Making Science a Vital Force in Foreign Policy," _Science_, CXXXIII (Jan. 6, 1961), 24-25.

2. L. D. Jaffe, R. R. McDonald, and W. J. Schimandle, "Preliminary Study of a National Space Effort," May 9, 1961 (hereafter "Preliminary Study"); Pickering to Senior Staff, April 25, 1961, File 31.2, Lee DuBridge Papers, Caltech Archives, Pasadena; John M. Logsdon, _The Decision to Go to the Moon: Project Apollo and the National Interest_ (Cambridge, Mass., 1970), p. 112.

3. "Preliminary Study," emphasis added; Robert V. Meghreblian to Pickering and F. E. Goddard, May 3, 1961, JPLHF 3-1090.

4. On credibility generally see Jonathan Schell, _The Time of Illusion_ (New York, 1976), esp. pp. 133-134. On Kennedy, technology, and the Third World see Theodore Sorensen, _Kennedy_ (New York, 1965), p. 524. On appearance and reality in matters of credibility Sorensen (p. 678) offers this revealing analysis of the Cuban missile crisis:

> To be sure, these Cuban missiles alone, in view of all the other megatonnage the Soviets were capable of unleashing upon us, did not substantially alter the strategic balance _in fact_ -- unless these first installations were followed by so many more that Soviet military planners would have an increased temptation to launch a pre-emptive first strike. But that balance would have been substantially altered _in appearance_; and in matters of national will

and world leadership, as the President said later,
such appearances contribute to reality.
(Emphasis added.)

5. "Preliminary Study."

6. Meghreblian to Pickering and F. E. Goddard, May 3, 1961, JPLHF 3-1090; Pickering, "Acceleration of the U. S. Space Program, n.d., ca. May 1961, JPLHF 3-1107.

6a. Sorensen, Kennedy, pp. 524, 525, 608.

7. Public Papers of the Presidents: Kennedy, 1961 (Washington, 1962), pp. 396-406; R. Cargill Hall, Lunar Impact: A History of Project Ranger (Washington, 1977), p. 120.

8. Hall, Lunar Impact, p. 65; [James Burke?], "BEAT THE RUSSIANS: A 'First' at Something with Public Recogniz," roll 211-4, JPL Vellum Center.

9. Hall, Lunar Impact, pp. 46-49.

10. Eberhardt Rechtin to Brian Sparks, Feb. 20, 1963, Ranger 5 Failure Investigation Board interview with John Small, Oct. 30, 1962, box 3, shipment 1427, JPL Foothill D Records Storage Center.

11. Interview summaries, Ranger 5 Failure Investigation Board, ibid.

12. Ibid., esp. interviews with Burke, Nov. 2, 1962, Cummings, Nov. 6, 1962, Small, Oct. 30, 1962, and J. N. James, Nov. 2, 1962.

13. Ibid., esp. Cummings, Nov. 6, 1962; Hall, Lunar Impact, pp. 124-127, 164.

14. Hall, Lunar Impact, pp. 74-77. Burke's subordination of scientific experiments to engineering was apparent in a memorandum he wrote in March 1960: "Scientific experiments are an integral part of the planned program. By setting up scientific objectives for each round we force ourselves to consider system interactions that would not otherwise be apparent, and we develop kinds of equipment needed in the future. Scientific experiments, as such, are carried on a basis of non-interference with engineering measurements, but engineering development of scientific instrumentation is as important as other engineering developments in the spacecraft" ("Mission Objectives and Design Criteria for Ranger flights 3, 4, 5," March 9, 1960, roll 211-5, JPLVC).

15. Hall, Lunar Impact, p. 57.

16. Ranger 5 Failure Investigation Board interview with

R. Heacock, Oct. 30, 1962, box 3, shipment 1427; Hall, Lunar Impact, pp. 130-137.

17. Ibid., pp. 162-163.

18. Ranger 5 Failure Investigation Board interview with James, Nov. 2, 1962, box 3, shipment 1427.

19. This section is based substantially on Hall's indispensable Lunar Impact, primarily ch. 6, 9.

20. NASA, "Final Report of the Ranger Board of Inquiry," Nov. 30, 1962, p. 5, JPLHF 2-2463.

21. Burke to Robert J. Parks and Cummings, May 19, 1960, JPLHF 8-101; Abe Silverstein to Robert Seamans, Aug. 30, 1961, Aug. 30, 1961, Homer Newell Files, NASA History Office; Parks to H. M. Schurmeier, et al., Sept. 6, 1961, JPLHF 8-46.

22. Ranger 5 Failure Investigation Board interview with James, Nov. 6, 1962, box 3, shipment 1427.

23. Ibid.; The Mariner Mission -- 1962 (Pasadena, 1963), pp. 5, 10-11.

24. Ibid., p. 3; Planning Research Corporation,

"Reliability Assessment of the Mariner Spacecraft," Dec. 17, 1962, JPLHF 8-12; Hall, Lunar Impact, p. 160.

25. Newell to Frank R. Hammill Jr., May 8, 1963, Newell Files, NASA History Office; Newell to Joseph E. Karth in Subcommittee on NASA Oversight of the Committee on Science and Astronautics, House, Investigation of Project Ranger (Washington,1964), p. 5.

26. Hall, Lunar Impact, pp. 163-170.

27. Report of JPL Failure Investigation Board, "Ranger RA-5 Failure Investigation," Nov. 13, 1962, box 3, shipment 1427.

28. Ibid.; Morris to Pickering, Nov. 14, 1962, ibid. (emphasis in original).

29. Ibid.

30. Ibid. W. K. Victor, who felt that "the Mariner project was successful in spite of the management tools provided by the Laboratory organization rather than because of it," dissented from the recommendation to replace Burke. (Victor to RA-5 Failure Investigating Board, Nov. 13, 1963, ibid.)

31. NASA, "Final Report of the Ranger Board of Inquiry," Nov. 30, 1962, JPLHF 2-2463.

32. Ibid. See also the discussion of the two investigating boards in Hall, Lunar Impact, ch. 11.

33. Ibid.

34. Hall, Lunar Impact, pp. 176-182.

35. Ibid.